

Claims

- [c1] 1.A phosphor blend comprising at least two phosphors selected from the group consisting of (a) $\text{Sr}_2\text{P}_2\text{O}_7:\text{Eu}^{2+}, \text{Mn}^{2+}$; (b) $(\text{Ca}, \text{Sr}, \text{Ba})_a(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH}):\text{Eu}^{2+}, \text{Mn}^{2+}$ wherein a is in a range from about 4.5 to and including 5; (c) $3.5\text{MgO} \cdot 0.5\text{MgF}_2\text{GeO}_2:\text{Mn}^{4+}$; (d) $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; (e) $(\text{Sr}, \text{Ba}, \text{Ca})_5(\text{PO}_4)_3(\text{Cl}, \text{OH}):\text{Eu}^{2+}$; (f) an europium-activated aluminate phosphor selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$, and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; and (g) an europium and manganese co-activated aluminate phosphor selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}, \text{Mn}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}, \text{Mn}^{2+}$, and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}, \text{Mn}^{2+}$; said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light having wavelengths in the visible spectrum.
- [c2] 2.The phosphor blend of claim 1, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.
- [c3] 3.The phosphor blend of claim 1, wherein a is preferably in a range from about 4.7 to and including 5, and more preferably from about 4.9 to and including 5.
- [c4] 4.The phosphor blend of claim 1, wherein said emitted light is white light.
- [c5] 5.The phosphor blend of claim 4, wherein said white light has color coordinates substantially on a black body locus of a CIE chromaticity diagram.
- [c6] 6.A phosphor blend comprising a mixture of $\text{Sr}_2\text{P}_2\text{O}_7:\text{Eu}^{2+}, \text{Mn}^{2+}$ and at least one phosphor that is selected from the group consisting of (a) $(\text{Ca}, \text{Sr}, \text{Ba})_a(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH}):\text{Eu}^{2+}, \text{Mn}^{2+}$ wherein a is in a range from about 4.5 to and including 5; (b) $3.5\text{MgO} \cdot 0.5\text{MgF}_2\text{GeO}_2:\text{Mn}^{4+}$; (c) $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; (d) $(\text{Sr}, \text{Ba}, \text{Ca})_5(\text{PO}_4)_3(\text{Cl}, \text{OH}):\text{Eu}^{2+}$; (e) an europium activated aluminate phosphor selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$, and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$;

and (f) an europium and manganese co-activated aluminate phosphor selected from the group consisting of $(\text{Ba,Ca,Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+},\text{Mn}^{2+}$, $(\text{Ba,Ca,Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+},\text{Mn}^{2+}$, and $(\text{Ba,Ca,Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+},\text{Mn}^{2+}$; said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light having wavelengths in the visible spectrum.

[c7] 7.The phosphor blend of claim 6, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.

[c8] 8.The phosphor blend of claim 5, wherein a is preferably in a range from about 4.7 to and including 5, and more preferably from about 4.9 to and including 5.

[c9] 9.A phosphor blend comprising a mixture of $(\text{Ca,Sr,Ba})_a(\text{PO}_4)_3(\text{F,Cl,OH}):\text{Eu}^{2+},\text{Mn}^{2+}$ wherein a is in a range from about 4.5 to and including 5 and at least one phosphor that is selected from the group consisting of (a) $\text{Sr}_2\text{P}_2\text{O}_7:\text{Eu}^{2+},\text{Mn}^{2+}$; (b) $3.5\text{MgO} \cdot 0.5\text{MgF}_2\text{GeO}_2:\text{Mn}^{4+}$; (c) $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; (d) $(\text{Sr,Ba,Ca})_5(\text{PO}_4)_3(\text{Cl,OH}):\text{Eu}^{2+}$; (e) an europium activated aluminate phosphor selected from the group consisting of $(\text{Ba,Ca,Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}$, $(\text{Ba,Ca,Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$, and $(\text{Ba,Ca,Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+},\text{Mn}^{2+}$; and (f) an europium and manganese co-activated aluminate phosphor selected from the group consisting of $(\text{Ba,Ca,Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+},\text{Mn}^{2+}$, $(\text{Ba,Ca,Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+},\text{Mn}^{2+}$, and $(\text{Ba,Ca,Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+},\text{Mn}^{2+}$; said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light having wavelengths in the visible spectrum.

[c10] 10.The phosphor blend of claim 9, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.

[c11] 11.The phosphor blend of claim 9, wherein a is preferably in a range from about 4.7 to and including 5, and more preferably from about 4.9 to and including 5.

[c12] 12.A phosphor blend comprising a mixture of $\text{Sr}_2\text{P}_2\text{O}_7:\text{Eu}^{2+}, \text{Mn}^{2+}$ and $(\text{Ca}, \text{Sr}, \text{Ba})_5(\text{PO}_4)_3(\text{F}, \text{Cl}, \text{OH}):\text{Eu}^{2+}, \text{Mn}^{2+}$; wherein a is in a range from about 4.5 to and including 5, and said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light having wavelengths in the visible spectrum.

[c13] 13.The phosphor blend of claim 12, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.

[c14] 14.The phosphor blend of claim 12, wherein a is preferably in a range from about 4.7 to and including 5, and more preferably from about 4.9 to and including 5.

[c15] 15.A phosphor blend comprising a mixture of phosphors having formulas $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{CeO}_2:\text{Mn}^{4+}$; $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; and an europium and manganese co-invented aluminate phosphors selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}, \text{Mn}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}, \text{Mn}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}, \text{Mn}^{2+}$; said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light having wavelengths in the visible spectrum.

[c16] 16.The phosphor blend of claim 15, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.

[c17] 17.A phosphor blend comprising a mixture of phosphors having formulas $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{CeO}_2:\text{Mn}^{4+}$; $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; and an europium and manganese co-activated aluminate phosphors selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}, \text{Mn}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}, \text{Mn}^{2+}$, and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}, \text{Mn}^{2+}$; said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light

having wavelengths in the visible spectrum.

- [c18] 18. The phosphor blend of claim 17, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.
- [c19] 19. A phosphor blend comprising a mixture of phosphors having a formula of $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2 : \text{Mn}^{4+}$; $(\text{Sr}, \text{Ba}, \text{Ca})_5 (\text{PO}_4)_3 (\text{Cl}, \text{OH}) : \text{Eu}^{2+}$; and an europium and manganese co-activated aluminate phosphor selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2 \text{MgAl}_{16} \text{O}_{27} : \text{Eu}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10} \text{O}_{17} : \text{Eu}^{2+}$, Mn^{2+} , and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3 \text{Al}_{14} \text{O}_{25} : \text{Eu}^{2+}, \text{Mn}^{2+}$; said phosphor blend being capable of absorbing electromagnetic radiation having wavelengths in a range from about 315 nm to about 480 nm and emitting light having wavelengths in the visible spectrum.
- [c20] 20. The phosphor blend of claim 19, wherein said phosphor blend preferably absorbs electromagnetic radiation substantially in a wavelength range from about 350 nm to about 410 nm.
- [c21] 21. A light source comprising: at least one LED that is capable of emitting electromagnetic radiation having wavelengths in a range from near UV to blue; least one phosphor material selected from the group consisting of (a) $\text{Sr}_2 \text{P}_2 \text{O}_7 : \text{Eu}^{2+}, \text{Mn}^{2+}$; (b) $(\text{Ca}, \text{Sr}, \text{Ba})_a (\text{PO}_4)_3 (\text{F}, \text{Cl}, \text{OH}) : \text{Eu}^{2+}, \text{Mn}^{2+}$ wherein a is in a range from about 4.5 to and including 5; (c) $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2 : \text{Mn}^{4+}$; (d) $\text{Sr}_4 \text{Al}_{14} \text{O}_{25} : \text{Eu}^{2+}$; (e) $(\text{Sr}, \text{Ba}, \text{Ca})_5 (\text{PO}_4)_3 (\text{Cl}, \text{OH}) : \text{Eu}^{2+}$; (f) an europium-activated aluminate phosphor selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2 \text{MgAl}_{16} \text{O}_{27} : \text{Eu}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10} \text{O}_{17} : \text{Eu}^{2+}$, and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3 \text{Al}_{14} \text{O}_{25} : \text{Eu}^{2+}$; and (g) an europium and manganese co-activated aluminate phosphor selected from the group consisting of $(\text{Ba}, \text{Ca}, \text{Sr})_2 \text{MgAl}_{16} \text{O}_{27} : \text{Eu}^{2+}, \text{Mn}^{2+}$, $(\text{Ba}, \text{Ca}, \text{Sr})\text{MgAl}_{10} \text{O}_{17} : \text{Eu}^{2+}, \text{Mn}^{2+}$, and $(\text{Ba}, \text{Ca}, \text{Sr})\text{Mg}_3 \text{Al}_{14} \text{O}_{25} : \text{Eu}^{2+}, \text{Mn}^{2+}$; and (h) mixtures thereof; said phosphor material being capable of absorbing said electromagnetic radiation emitted by said LED and emitting light having wavelengths in the visible spectrum.

- [c22] 22.The light source of claim 21, wherein said LED emits electromagnetic radiation in a wavelength from about 315 nm to about 480 nm.
- [c23] 23.The light source of claim 21, wherein a is preferably from about 4.7 to and including 5, and more preferably from about 4.9 to and including 5.
- [c24] 24.The light source of claim 17, wherein said LED preferably emits electromagnetic radiation from about 350 nm to about 410 nm.
- [c25] 25.A light source comprising: at least one LED that is capable of emitting electromagnetic radiation having wavelengths in a range from near UV to blue; and a phosphor material selected from the group consisting of $\text{Sr}_2\text{P}_2\text{O}_7:\text{Eu}^{2+}$, Mn^{2+} , $(\text{Ca},\text{Sr},\text{Ba})_a(\text{PO}_4)_3(\text{F},\text{Cl},\text{OH})\text{Eu}^{2+}$, Mn^{2+} wherein a is in a range from about 4.5 to and including 5, and mixtures thereof; said phosphor being capable of absorbing said electromagnetic radiation emitted by said LED and emitting light having wavelengths in the visible spectrum.
- [c26] 26.The light source of claim 25 wherein a is i preferably from about 4.7 to and including 5, and more preferably from about 4.9 to and including 5.
- [c27] 27.The light source according to claim 20, wherein said phosphor material further comprises a phosphor selected from the group consisting of (a) $3.5\text{MgO} \cdot 0.5\text{MgF}_2 \cdot \text{GeO}_2:\text{Mn}^{4+}$; (b) $\text{Sr}_4\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$; (c) an europium-activated aluminate phosphor selected from the group consisting of $(\text{Ba},\text{Ca},\text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}$, Mn^{2+} , $(\text{Ba},\text{Ca},\text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$, Mn^{2+} , and $(\text{Ba},\text{Ca},\text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$, Mn^{2+} ; and (d) an europium and manganese co-activated aluminate phosphor selected from the group consisting of $(\text{Ba},\text{Ca},\text{Sr})_2\text{MgAl}_{16}\text{O}_{27}:\text{Eu}^{2+}$, Mn^{2+} , $(\text{Ba},\text{Ca},\text{Sr})\text{MgAl}_{10}\text{O}_{17}:\text{Eu}^{2+}$, Mn^{2+} , and $(\text{Ba},\text{Ca},\text{Sr})\text{Mg}_3\text{Al}_{14}\text{O}_{25}:\text{Eu}^{2+}$, Mn^{2+} .